HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1934

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UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

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INTRODUCTION

The continued low prices of sugar and pineapples have resulted in an increase in attention given to the problem of the wisest utilization of the marginal and submarginal lands for the growth of other crops which are not at present being overproduced. The Territory is also faced with the problem of the best use of the acreage that will probably be taken out of production of the two leading crops—sugarcane and pineapples. While the sugar and pineapple producers maintain their own experiment stations primarily for working out the problems which arise in connection with their respective industries, they have been able to render valuable assistance in various cooperative activities looking to the further development of the minor agricultural industries throughout the islands.

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The development and application of an economical and rapid method of determining the fertilizer needs of diversified crops on various soil types, based on the Mitscherlich principle, has continued to constitute one of the outstanding projects of the station. Various crops, such as coffee, Macadamia nuts, potatoes, rice, soybeans, panicum (Para) grass, Sudan grass, Oriental kale, carrots, etc., have been studied by this method. Several improvements and additions to the equipment for use in the method were made during the year. The revolving type of table to hold the pots, as developed by the experiment station of the Hawaiian Sugar Planters' Association, was installed. An additional greenhouse was built. This is capable of carrying 14 revolving tables of 12 pots each (fig. 1).

FIGURE 1.—Mitscherlich pots mounted on revolving tables to secure maximum as well as uniform utilization of light. Each series of pots is placed on a separate revolving table. The tables are made to turn one revolution in about 10 minutes by means of an electric motor and a series of reduction gears. The tables are mounted on old automobile axles.

The Mitscherlich pot method offers especial promise under local conditions, as a means of studying plant nutrition and soil fertility. both from a fundamental as well as a practical standpoint. During the year a variety of crops was grown successfully in Mitscherlich pots, and it appears that nearly all of the ordinary root, tuber, leaf, or pod vegetable crops, as well as the various grasses, will grow normally (fig. 2).

A great advantage of being able to use various crops in supplementing a single indicator plant, like Sudan grass, is that the results are of immediate value without the necessity of first establishing the correlation between the indicator crop and the crop being studied. In addition, the growing of the crop itself in the pot test enables one to study specific problems of the crop not directly related to the available plant food.

Special technics are required for the successful growth of the various crops by the Mitscherlich pot method. For example, with potatoes, the whole tubers are pregerminated in coral sand until the developing stem has 2 or 3 small leaves. Uniform plants are then selected and the seed potato is cut away with a knife until about 15 grams of tissue remain. Three such plants are then transferred to each pot and allowed to grow to maturity. Frequent sprayings and dustings with bordeaux mixture, sulphur, and nicotine are required. With the succulent leaf crops, shading and humidifying with fine water spray are also necessary. With proper care, duplicates can be obtained with a difference no greater than 4 to 8 percent.

FIGURE 2.—*A*, Cabbage; *B*, carrots. A variety of vegetable crops can be grown in Mitscherlich pots. Response of these crops, in pots, to fertilizer gives promise of being a valuable indicator of field results.

With the realization that the results obtained at this stage of the work are often of qualitative value only, due to changes in technic which must inevitably result from further study, emphasis has been placed on technic rather than any attempt at close correlation with field results. Since every different crop grown in pots would require the development of a special technic, an attempt is being made to use one crop as an indicator for a group of closely related crops, the specific crop indicator being selected on the basis of hardiness, rapidity of growth, and response to fertilizer. For the leafy vegetables, Oriental kale (*Brassica oleracea acephala*) offers promise as

an indicator. It is hardy, not much attacked by insects, and grows rapidly. For the root crops, the red radish seems well adapted. It produces roots of large size in pots and grows rapidly. Preliminary tests with the various pod crops indicate that the bush beans grow better than the climbing varieties.

Continued search is being made for a general indicator crop to be used in place of Sudan grass. This grass has many desirable qualities as an indicator, chiefly uniform and rapid growth, ability to grow in very hot as well as cool weather conditions and very low experimental error among duplicates. In certain soils, however, it makes a very weak growth regardless of the fertilizer treatment. Another objection is its supersensitivity to phosphates. In many of the island soils the yield of the pot receiving nitrogen and potassium but no phosphorus is not more than 4 to 8 percent of that of pots receiving complete fertilizer (nitrogen, phosphorus, and potassium).[1] Much more exact measurement could be made of the differences between soils if a less phosphate-sensitive crop could be found. In this respect panicum (Para) grass (*Panicum purpurascens*) is being tried. For planting materials, one node with an inch section of stem is used. Ten of these are inserted into each pot without pregermination. If care is used in selection of planting material near to the vigorously growing tips, excellent growth and uniformity can be obtained. In poor soils it appears to make a more vigorous growth than Sudan grass. Tests are being made to determine how small an experimental error is possible.

Satisfactory progress was made in all of the 43 active projects of the station, although several other projects were placed on the inactive list owing to lack of adequate funds and personnel for their prosecution.

New lines of work undertaken included (1) life-history and growth-habit studies of certain grasses and legumes under tropical conditions, (2) studies as to the relative merits of various types of plantation back-yard poultry houses, (3) battery systems for laying and breeding hens, (4) artificial illumination for laying stock, (5) tree kale as a source of green feed for poultry, (6) vitamin transfer between certain plant tissues, and (7) chemical studies of the passion fruit.

Old lines of work completed or suspended included (1) the feeding of cane molasses to dairy cows, (2) sorehead control of baby chicks and poults, (3) sex determination of day-old purebred chicks, (4) value of taro and fermented poi in poultry-fattening rations, and (5) determination of the iodine content of Hawaiian sea foods.

Experiments were carried out by the agronomy division at various places throughout the Territory with range grasses, pigeonpeas, rice, green manures, forage, and vegetable crops.

The manuscript for a bulletin, giving the results of feeding cane molasses to dairy cows over a period of 8 years, was submitted for publication (see also p. 24). A bulletin showing the results of feeding cane molasses to swine was published (4).[2] An experimental

[1] In these and the fertilizer pot experiments referred to in other later places in this report, the nitrogen was, unless otherwise specified, supplied in the form of ammonium nitrate, phosphorus as sodium acid phosphate (monobasic), and potassium in the form of potassium sulphate.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

dairy herd of 51 animals of all classes was maintained throughout the year, as well as a small herd of swine and a flock of poultry of sufficient size for the carrying out of approved experiments.

The chemical division of the station devoted its energies largely to the determination of the fertilizer requirements of the more promising minor crops (coffee, Macadamia nuts, rice, potatoes, etc.) and to the solution of technical problems arising in connection with such crops as the Macadamia nut. Special chemical investigations were also made of the iodine content of Hawaiian sea foods, as well as certain chemical constituents of avocados and passion fruit. (See also pp. 27, 28.)

In the horticultural division special attention was given to the development of an economic tropical aboretum, cultural and breeding studies of coffee varieties, akala berries, passion fruit, avocados, mangoes, etc. A bulletin on citrus in Hawaii (*6*) giving the results of 25 years' work was published, as well as a circular on the propagation of various trees, shrubs, and plants by cuttings (*7*).

The nutrition laboratory determined the nutritive constituents of numerous local fruits and made vitamin studies of certain important vegetables, fruits, and sea foods. A bulletin was published concerning Japanese foods commonly used in Hawaii (*5*).

The subject of poi manufacture and fermentation was studied by the division of bacteriology of the University of Hawaii, in collaboration with the station, and a bulletin on the subject was published by the station (*1*).

The poultry division developed the "live virus" method of sorehead control to a high degree of efficiency, and to a point where it was deemed advisable to turn the project over to a local commercial interest to furnish the vaccine to interested poultrymen throughout the islands. A station circular was issued on sorehead control. Caponizing also received attention and a circular on this subject was published (*2*). One Barred Plymouth Rock hen completed her laying year with a total of 313 eggs to her credit.

The soil physics division continued its studies of the water-holding peculiarities of Hawaiian soils.

The Haleakala substation (see also p. 30), on the Island of Maui, continued its experiments with range grasses at varying elevations, pigeonpeas, potatoes, and numerous other field crops and vegetables. The Kona substation (see also p. 31), on the Island of Hawaii, devoted its energies largely to the development of plantings of various species of coffee, avocados, mangoes, and numerous other fruits which possess promise under the local conditions. Selection work with Macadamia nuts and fertilizer experiments with coffee were also under way throughout the year. During the year an adjoining tract of 1.66 acres of arable land was acquired and is being planted to various introduced species of coffee for use in breeding work and variety tests.

The station budget for the year was $86,650, made up as follows: Territorial and university special funds, $24,000; Hatch fund, $15,000; Adams fund, $11,000; United States Department of Agriculture funds, $36,650. The last item was subsequently reduced by impoundments to the United States Treasury, which totaled $4,075. The budget for the previous year totaled $94,500.

PROJECTS

Research projects active during the year and their leaders were: Correlation between the magnitude of the sesquioxide ratio in an extracted soil colloid and soil-moisture availability (H. A. Wadsworth); breeding and selection of pigeonpeas, breeding and yield studies of forage crops, life-history and growth-habit studies of grasses and legumes under tropical conditions (C. P. Wilsie); relation of chemical composition of range grasses to pasture management (D. W. Edwards); varietal, cultural, and propagation studies of citrus, culture and breeding of Hawaiian raspberries (akala berry, *Rubus* sp.), and varietal, cultural, and propagation studies of Macadamia nuts (W. T. Pope); factors affecting chemical composition of Macadamia nuts (J. C. Ripperton); varietal, cultural, and propagation studies of coffee (W. T. Pope); rejuvenation of old coffee plantings, and nutrition and fertilizer studies of the coffee plant (J. C. Ripperton); variety tests and breeding studies of vegetable crops (C. P. Wilsie); cane molasses for dairy cows, sprouted oats for correcting breeding problems of dairy cows and brood sows, and sugar and molasses feeding of swine (L. A. Henke); control of sorehead of baby chicks and poults, sex determination of day-old purebred chicks, batteries for laying and breeding hens, artificial illumination for laying hens, gizzard-worm investigations (C. M. Bice); vitamin studies of Hawaiian foods and feeds, chemical and biological studies of protein in pigeonpeas, chemical and biological studies of the opihi (shellfish), studies of the transfer of vitamin B from rice bran to various types of plant tissues as a result of pickling them with salt and rice bran (C. D. Miller); and study of the sterol content and vitamin value of avocado oil, determination of the iodine content of Hawaiian foods, and chemical studies of Hawaiian plants, (1) poisonous plants, (2) passion fruit (L. N. Bilger).

PUBLICATIONS

The following is a list of publications of the station during the year covered by this report:

Report of the Hawaii Agricultural Experiment Station, 1933; Bulletin 68, Japanese Foods Commonly Used in Hawaii, by C. D. Miller; Bulletin 69, Cane Molasses as a Supplement to Fattening Rations for Swine, by L. A. Henke; Bulletin 70, The Manufacture of Poi from Taro in Hawaii: With Special Emphasis upon Its Fermentation, by O. N. Allen and E. K. Allen; Bulletin 71, Citrus Culture in Hawaii, by W. T. Pope; Circular 7, Capons and Caponizing, by C. M. Bice; Circular 8, Fowl Pox (Sorehead) Control by Vaccination, by C. M. Bice; and Circular 9, Propagation of Plants by Cuttings in Hawaii, by W. T. Pope.

Articles contributed by members of the station staff and published elsewhere than in the regular station series of bulletins and circulars included the following: The Nutritive Value of the Mountain Apple (*Eugenia malaccensis or Jambosa malaccensis*), by C. D. Miller, R. C. Robbins, and K. Haida (Philippine Jour. Sci. 53: 211–222. 1934); Local Crops High in Food Value, by C. D. Miller (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 50); An Inexpensive Water-Stage Register for Plantation Field Ditches, by H. A. Wads-

worth (Hawaii. Planters' Rec. 37: 92–95. 1933); Some Physical Constants for Certain Hawaiian Sugar Cane Soils, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 106–113. 1933); A Historical Summary of Irrigation in Hawaii, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 124–162. 1933); Irrigation is Highly Developed, by H. A. Wadsworth (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 11); Soil Moisture and the Sugar Cane Plant, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 111–119. 1934); On setting the Crest Elevation for the Parshall Flume, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 157–159. 1934); The Dairy Industry of Hawaii, by L. A. Henke (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 16); Pineapple Plants as Forage for Cattle, by L. A. Henke (Pineapple Quart. 4: 1–6. 1934); Territory Can Grow Dairy Feed, by C. P. Wilsie (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 18); Commercial Poultry Production and Marketing in Hawaii, by H. L. Chung, A. S. T. Lund, and C. M. Bice (Univ. Hawaii Ext. Bull. 20. 1934); Poultry Industry Grows Rapidly, by C. M. Bice (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 23); Fertilizing is Good Investment, by J. C. Ripperton (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 10); A Comparison of Legume Intercycle Crops for Pineapples, by O. C. Magistad, N. King, and O. N. Allen (Jour. Amer. Soc. Agron. 26: 372–380. 1934); More Interest in Fruit Growing, by W. T. Pope (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 36); and Research Aids Minor Industries, by J. M. Westgate (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 9).

SOILS

Continued work on factors affecting the ratio of the moisture equivalents of soils to their permanent wilting percentages indicated that the numerical value of this conventional ratio is, except in rare cases, independent of the textural classification. No significant differences in the ratios were found when Hawaiian soils were diluted with as much as 90 percent coarse silica sand. In still further dilution it is probable that the ratios would increase. The large probable errors involved with each of the determinations when large amounts of sand were used, however, made the results unreliable.

The necessity of working with small amounts of material in studying the availability ratios of the individual constituents of the soil has resulted in an indirect measure of these values. When this procedure is used samples of the soil separate in question are wetted to the moisture equivalent and brought into equilibrium with streams of air of known relative humidities. The probable wilting percentage may be deduced from the moisture contents and the surface forces involved at each of the equilibria.

No great precision may be expected from this procedure, but it promises to be a useful tool in locating the range of available soil moisture with separates that are available only in small quantities.

FIELD CROPS AND FORAGE PLANTS

RICE

The cooperative fertilizer experiments begun last year with the agricultural extension service of the University of Hawaii and with

the rice growers on the Island of Kauai were continued. The first crop was harvested and the crop replanted and fertilized for the second season's growth. The results show that for this soil nitrogen is the chief fertilizer element which is lacking. On the phosphorus-potassium plats without nitrogen the yield averaged 31 bags (100 pounds each) of paddy per acre; with nitrogen, the yield increased to 56 bags. There were slight but not significant responses to phosphorus and potassium. The nitrogen was in the form of ammonium sulphate only. In this experiment the phosphorus and potassium were applied in small furrows and the seed drilled in soon after. The nitrogen was applied about 45 days later, about the customary time for the application of complete fertilizer in ordinary practice.

Pot tests with rice, by the Mitscherlich method, using soil taken from the experimental field, were carried out in the station greenhouses. These pot experiments showed good correlation with the field results. A simple device for maintaining a constant depth of water has been found effective. A 1-quart bottle is held inverted at the edge of the pot by means of a wood-and-wire frame. The neck of the bottle extends down inside of the pot to the level at which the water is to be maintained. The bottle is filled with water once a day and the water keeps at a constant level after the manner of automatic poultry drinking fountains. Terra-cotta pots 10 inches in diameter and holding about 6 kilograms of soil are used. These are pretreated with paraffin dissolved in gasoline to render them impervious.

As an aid to the rice growers, soil samples sent in from the Moloaa, Hanapepe, and Wailua districts of Kauai were tested by the pot method for their response to the three fertilizer constituents. The results have been sufficiently conclusive to warrant the recommendation that the fertilizer practice be changed so as to maintain the nitrogen at its present level and reduce the phosphorus and potassium to one-half the present amounts. In the meantime any possible deleterious effect of this change is being studied by means of the continuous field experiments. The use of nitrogen only is not recommended, however, as indications have been obtained that the quality of the rice is adversely affected by nitrogen alone. Fertilizers are expensive, and reduction in the cash outlay in the production of rice in Hawaii is imperative if the industry is to persist.

PIGEONPEAS

Isolating and purifying strains by self-fertilization was continued. Selfing was accomplished by covering unopened buds with closely woven muslin bags and allowing the seed to ripen in the bags.

Experiments to determine the extent of natural crossing between varieties were completed. Approximately 15 percent of natural hybrids were obtained in progenies of open-pollinated plants that had been growing in rows adjacent to other varieties. A complete report of this work was submitted for publication in the Journal of Agricultural Research.

SOYBEANS

The testing of varieties was continued, emphasis being placed on those that were considered promising for green vegetable use. Yellow Biloxi Hybrid, a selection obtained through the courtesy of P. H. Kime, North Carolina Experiment Station, appeared to be quite

desirable from the standpoint of yield and quality. Two varieties, F. P. I. No. 80483 and 81780, secured through the courtesy of W. J. Morse, U. S. Department of Agriculture, gave excellent results in cooking tests for use as green vegetable beans. Twenty-one new varieties were obtained during the year from Dr. Morse for adaptation studies.

GRASSES AND LEGUMINOUS FORAGE CROPS

ADAPTATION STUDIES

Considerable attention was given to the introduction and establishment of more desirable species for pasture and green fodder use (fig. 3). Through the maintenance of a series of grass gardens at

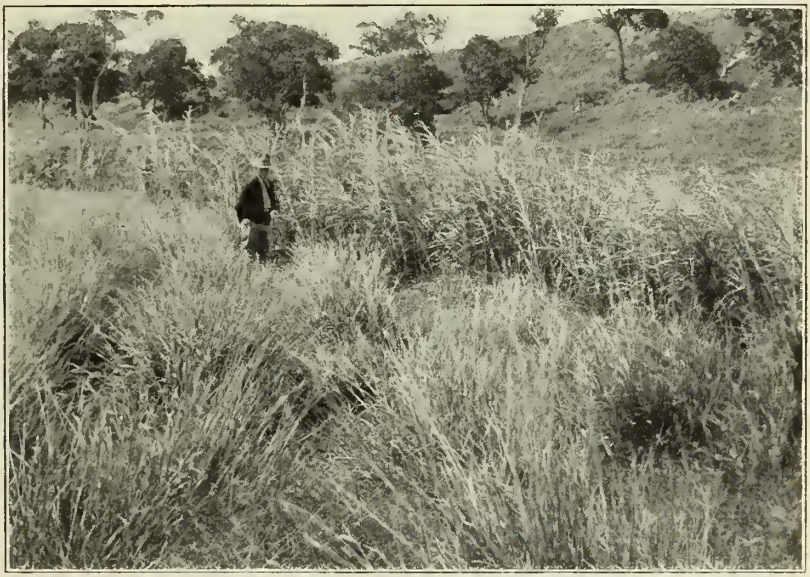

FIGURE 3.—Guinea grass (*Panicum maximum*) in foreground; elephant grass (*Pennisetum purpureum*) in background. These coarse grasses are making a vigorous growth at 2,200 feet altitude on the windward side of Hawaii. In this section, where the sod is nearly pure Hilo grass (*Paspalum conjugatum*), these coarse grasses offer excellent possibilities in the development of fattening paddocks.

the central station in Honolulu, the Haleakala substation on Maui, and cooperating ranches on the various islands, a large number of grass and legume species were studied for adaptation to different ecological conditions. One of the striking observations made was that kikuyu grass (*Pennisetum clandestinum*) was successfully established over a wide range of climatic conditions at elevations of from sea level to 6,400 feet. Rhodes grass (*Chloris gayana*) also succeeded under a wide range of conditions, but its adaptation is undoubtedly centered below 4,000 feet elevation. Wetland trefoil (*Lotus uliginosus*) was one of the most promising legumes, growing well at from 2,000 to 4,000 feet elevation and being particularly adapted to mixed plantings, making an excellent growth with kikuyu grass.

At the higher elevations, beginning at about 3,000 feet and extending up to 6,000 feet and higher, many of the Temperate Zone

species and particularly *Lolium perenne*, *L. multiflorum*, *Festuca elatior*, *Bromus unioloides*, and *Dactylis glomerata* were very promising. At these levels the most successful legumes were perennial Australian red clover (*Trifolium pratense* var.), New Zealand white clover (*T. repens*), several vetches (*Vicia* spp.), and alfalfa (*Medicago sativa*).

Due to the commonly experienced periods of severe drought such as was prevalent in many of the ranch areas in the summer of 1933, the establishment of drought-resistant species is of particular importance. Species that showed remarkable drought-resistant qualities were Rhodes grass, giant Bermuda (*Cynodon dactylon* var.), molasses grass (*Melinis minutiflora*), pigeonpea (*Cajanus indicus*), birdsfoot trefoil, and alfalfa.

New introductions, which appeared to be worthy of more extensive trials, were *Andropogon rufus*, *Indigofera hirsuta*, and *Stylosanthes guyanensis* var. *subviscosus*. These were obtained through the courtesy of the Experiment Station for Agrostology, Deodoro, Brazil. The agricultural extension service of the University of Hawaii cooperated in these adaptation studies.

LIFE-HISTORY AND STRAIN STUDIES

Preliminary studies were made in the flowering and seeding habits of Napier and Merker grasses, two varieties of *Pennisetum purpureum*. The blooming period of a single flowering head was found to extend over a number of days, the anthers emerging about 4 days later than the stigmas. Cross-pollination seems to be the rule in this species, although some seed was produced under vegetable-parchment bags from inflorescences covered before stigma emergence. Seedlings from both open-pollinated and selfed plants of both varieties were grown. A large number of growth types and distinct morphological variations have been noted in these seedling progenies, and the selection of superior forage strains seems quite feasible. As this species is propagated commercially by asexual means, strains possessing hybrid vigor or other desirable factor combinations could be maintained readily without the necessity of obtaining them in a homozygous condition.

Similar studies were also started with Sudan grass (*Sorghum vulgare sudanense*), guinea grass (*Panicum maximum*), and panicum (Para) grass, (*P. purpurascens*).

EFFECT OF LOCATION, SPECIES, AND SEASON ON QUALITY OF PASTURE GRASSES

Bimonthly harvests during a period of 14 months of grasses from the four grass gardens located on the Parker ranch were completed. Two hundred samples were each analyzed for moisture, total and silica-free ash, protein, calcium, and phosphorus. Unusually dry weather made it impossible to get a complete series of samples from each location. The results, however, showed a number of differences in quality of the grasses due to location, species, and season, which were statistically significant. For this comparison, five grasses were used: *Phalaris tuberosa*, paspalum (*P. dilatatum*), Rhodes grass (*Chloris gayana*), tall fescue (*Festuca elatior*), and kikuyu (*Pennisetum clandestinum*). With the exception of the last named, the grasses were clipped close to the crown of the stool every 2 months

so that the samples represented a 2-month growth. In the case of kikuyu, a creeping grass, only the fresh growing tips were taken for analysis. Most striking was the effect of location on the phosphorus content of the grasses. The poorest location (the leeward, dry grass garden) was scarcely 30 percent of the best in this constituent. The percentage of calcium was also affected, the windward, wet location being the poorest. Protein, on the other hand, was remarkably constant for the four locations.

Using the so-called "pairing method" of statistical analysis, it was possible to show significant differences among the five species. Season, too, seemed to have an effect, the poorest quality being found during the season of least growth, i. e., the cold winter months. Of the three factors—location, species, and season—the first named had much the greatest effect on the mineral content. The differences between the grass species on this basis of comparison were generally not great.

QUALITY OF FORAGE AS AFFECTED BY FERTILIZERS AND STIRRING THE SOIL

Former experiments with top-dressing of pastures with nonnitrogenous fertilizers showed a general lack of response except in cases of extreme deficiency. This, together with the oft-noted stimulation resulting from plowing and disking of the pasture sod, suggested the possibility that the fertilizer was not carried down to the grass roots or that the sod required stirring in order to stimulate the absorption of the fertilizer. To test this hypothesis, an experiment was begun on Grove farm, Kauai, comparing the effect of fertilization alone, fertilization plus plowing, and plowing alone. The fertilizer consisted of 1,000 pounds of phosphate fertilizer per acre—600 pounds as raw rock and 400 pounds as superphosphate. The area being used is one that is reputed to produce forage deficient in phosphates.

FRUITS, VEGETABLES, AND NUTS

AKALA OR NATIVE RASPBERRY AND OTHER RUBUS SPECIES

During the past year this work has included a study of both native and exotic species. Practically all but the most recent introductions are growing in a wild state as a part of the natural vegetation. The kinds of *Rubus* most commonly found consist of the akala (native raspberry) of two species, *Rubus hawaiiensis* and *R. macraei*, the thimbleberry (*R. rosaefolius*), and several varieties of American blackberries, dewberries, and raspberries.

The akala grows in moist land at altitudes ranging from 2,500 to 7,000 feet. In places, the two species form the main under-shrubbery of the forest and occasionally occur in mixed stands. The plants are eagerly devoured by livestock, and in range sections only plants in places inaccessible to the livestock may be found in fruit. Where the animals are kept out, as in new forest reserves, the plants spring up quickly and in great numbers as root suckers and seedlings. Seeds no doubt are disseminated to a considerable extent by birds. The stems and branches of the current year's growth of both species are more or less covered with tender green spines, but these are shed with the bark during the growth of the

second year as the stems become woody. The plants are not regarded as undesirable.

Rubus hawaiiensis is of uprignt form and often reaches a height of 8 to 10 feet. The individual plant usually consists of a clump containing several upright woody stems which continue to grow for a number of years, and in favorable conditions each may attain a diameter of 1.5 or 2 inches. Ordinarily, the fruit begins to ripen by April 1 and may be found as late as July. At maturity, the fruit averages 1.25 inches in diameter and occurs in two varieties, the dark purple and the yellow. The color of the fruit, however, is the only character distinguishing them. The flavor is often fair. *R. macraei* is a deciduous form with long arched canes with spines and scaly bark very similar to *R. hawaiiensis* but is later in coming into fruit, its season of bearing being from mid-July to November. The fruit averages 1 to 2 inches in diameter and is of a blue-black color and possesses various degrees of bitterness. These two species have been found on all of the larger islands except Oahu, but in this experiment was transplanted to 3,500 feet altitude on Oahu from the Island of Hawaii. Their cultivation has been undertaken at the Kona substation, 1,500 feet altitude, but the plants have not been vigorous and have failed to fruit.

The thimbleberry (*Rubus rosaefolius*), indigenous to southeastern Asia and the Philippines, is of early introduction into Hawaii. It now grows as a part of the natural vegetation in many places from near sea level to an altitude of 6,500 feet. The attractive but insipid light-red fruit is edible but the species is generally considered a pest. The canes and branches are thorny and the plants utilize considerable land in pastures and elsewhere which is desired for other plants.

Blackberries of several varieties, introduced many years ago, have formed thickets in several parts of the Territory. Although the fruit is used considerably, there is fear that they may soon become a very undesirable pest. The exact species has not as yet been satisfactorily determined. There are evidently two varieties, the most common being an evergreen type occurring on the Islands of Hawaii, Maui, and Oahu, and a deciduous form near the village of Holualoa on the Island of Hawaii. A few plants of the mammoth thornless blackberry were recently introduced, and, with two varieties of the dewberry, are in cultivation at the central station in Honolulu. The latter consists of a few plants each of the Youngberry and the Gardena dewberry. These, and the mammoth thornless blackberry, are being cultivated at several different elevations to determine their action under Hawaiian conditions. Former introductions of raspberries have failed to endure. Recent introductions by the station have been made from the mainland of the United States. These American varieties also have mostly died. One species from the Philippines, *R. niveus*, and a wild form from Java, have made considerable vigorous plant growth but as yet have shown but little inclination to fruit.

Not finding sufficient blossoms in the trial plats for hybridizing in April 1934, it was decided to collect pollen from blackberry plants in the Kilauea section of Hawaii and from another variety growing in the edge of the woods at an altitude of about 2,000 feet near

Holualoa, North Kona, and from the wild thimbleberry (*R. rosaefolius*) in South Kona, Island of Hawaii. The flowers were collected on April 19 and taken to a forest reserve on Mount Hualalai at 6,000 feet, where there is a good stand of *R. hawaiiensis* and *R. macraei*. Forty flowers of the native species were hand-pollinated and covered with cellophane bags, which, at that high, cool location in the partial shade of the woods, proved very satisfactory. Thirty-two days after pollination, a considerable number of the hybridized flowers had developed into fruit.

POTATOES

Variety tests of potatoes conducted on Oahu and Maui continued to show the superiority of the Bliss Triumph among the early red-skinned types and British Queen among the white varieties. The new variety, Katahdin, grown from Oregon seed stocks, gave excellent results in preliminary trials.

Nine varieties of potatoes were imported from New Zealand through the courtesy of the New Zealand Government Pure Seed Station. These were compared with Bliss Triumph and Earliest-of-All varieties grown in Hawaii. Only one of the New Zealand varieties gave a yield that compared favorably with the American varieties, and this (Up-to-Date) produced at the rate of 129 hundredweight per acre as compared to Waimea-grown Triumphs that produced 160 hundredweight per acre. These New Zealand varieties did not seem to be well adapted to Hawaiian conditions. Although all varieties were certified in New Zealand, the percentage of virus diseases was quite high in the field plats, showing, perhaps, that under Hawaiian climatic conditions the development of those diseases is more pronounced than under the cooler conditions of New Zealand.

Experiments on the production of disease-free seed stocks of the Triumph variety in Hawaii indicated that excellent seed potatoes could be grown at high elevations (5,000 feet) if the fields were carefully rogued for all diseased and weak plants. Yields obtained from such locally produced seed were higher (in variety tests) than those obtained from any other seed lot, including mainland certified seed of the same variety.

Three potato-fertilizer experiments were conducted on the Island of Oahu in cooperation with the local pineapple industry (fig. 4). These experiments consisted of comparisons of 9 treatments with 10 replications each. The treatments included 4 different amounts of phosphorus, in form of superphosphate, 2 of nitrogen, in form of ammonium sulphate, and only 1 of potassium, in form of potassium sulphate. The results showed in all cases a marked response to increments of phosphorus even in amounts as high as 1,000 pounds of superphosphate per acre. The plats receiving ample nitrogen and potassium but no phosphorus gave a yield of about 40 bags (100 pounds each) of potatoes per acre, while the yield when phosphorus was applied averaged 110 bags per acre. The response to nitrogen was variable, depending on the soil, the average being an increase of about 25 bags per acre over the phosphorus-potassium plats. Response to potassium was nil in all cases. For this type of soil, which is the ordinary red upland soil commonly used for pineapples,

a fertilizer mixture containing 12 percent nitrogen, 30 percent phosphoric acid (P_2O_5), and 6 percent potash (K_2O), at the rate of about 800 pounds per acre, is recommended. On the basis of the relatively low cost of fertilizer as compared with the other costs incident to growing potatoes in Hawaii, this high rate of application appears justified on the basis that it insures sufficient plant food for a bumper crop, given favorable weather conditions.

SWEETPOTATOES

Seventy varieties were tested for yield and 20 of these were used in cooking tests. Many were found to have rather poor quality for baking, being dry and tasteless. A few, Laupahoehoe, Madeira,

FIGURE 4.—Potato-fertilizer experiment on lands of a local pineapple company. Note the small growth of the nitrogen-potassium (no phosphate) plat in the center foreground and right center in the background. Spraying with bordeaux mixture is being done with a type of machine used by the local industry for spraying the pineapples with iron sulphate.

Japanese Brown Sweet, Pumpkin Yam, and several new selections from the Union of Soviet Socialist Republics had excellent cooking qualities. A collection of Hawaiian varieties has been introduced at the station through the courtesy of J. S. B. Pratt, of Eleele, Kauai.

SWEET CORN

Due to the susceptibility of sweet-corn varieties to the corn-stripe disease, efforts are being made to develop resistant sweet-corn hybrids. Guam corn shows little injury from this disease and is being used in the breeding work. Crosses have been made between Guam and Surcropper Sugar, Narrow Grain Evergreen, Country Gentleman, and Golden Cross Bantam. So far there has been some evidence of disease resistance in the Guam sweet-corn hybrids, and the work is to be continued. In these crosses many types intermediate between the true starchy and sugary types have been noted.

CABBAGE

Two field experiments with Copenhagen Market cabbage were made in the volcano district, Island of Hawaii. One was on virgin soil, to determine the requirements for nitrogen, phosphorus, and potassium. The first crop showed a marked deficiency of both nitrogen and phosphorus, even though it was recently cleared forest land. An earlier experiment on a nearby cultivated area had shown a good supply of phosphorus in the soil. The discrepancy was, in all probability, due to the residual effect of previous fertilizations and points to the desirability, wherever possible, of conducting all field experiments for a period of two crops in the same rows. Especially is this necessary in the gardening districts where very heavy applications of fertilizer are made. It has been found that the second crop will show very marked deficiencies, which were completely masked in the first crop. The other experiment in this district is designed to determine the economic rate of application of a complete fertilizer for cabbage.

The soil of the volcano district is made up of volcanic ash from which certain of the fertilizer elements leach readily. Farmers, for that reason, find it necessary to apply fertilizer as many as three or four times for a single crop of cabbage. An experiment has been planned to study the feasibility of using organic forms of fertilizer instead of the cheaper mineral forms.

At Waimea, Island of Hawaii, a fertilizer experiment with cabbage was carried through the second crop. The first crop showed little deficiency of nitrogen, phosphorus, or potassium. The second crop showed a distinct need of phosphorus with moderate deficiencies of both nitrogen and potash. The third crop in the same lines is now being grown. In connection with each of these field experiments, pot tests were made with Sudan grass, as well as cabbage and kale. A very acceptable correlation appears possible with both Sudan grass and kale. The field experiments were made in cooperation with the agricultural extension service of the University of Hawaii.

LIMA BEANS

Several selections of Hopi lima beans, introduced through the courtesy of W. W. Mackie, University of California, gave excellent yields as compared with Fordhook bush and Henderson bush varieties. The Hopi lima strains showed a definite perennial tendency and bore two good crops of seed. Two of these strains showed resistance to the root-knot nematode, while the others, as well as the standard varieties, were very susceptible.

LETTUCE

The breeding of lettuce for adaptation to low elevation conditions was continued. Hybrids between Mignonette and Selection 1801 were promising, showing the fine heading characteristics of the Mignonette parent and the larger size of the 1801. The season was not favorable for the production of solid heads of good size, but an excellent crop of seed was harvested for future plantings.

MISCELLANEOUS CROPS

Variety tests were conducted with taro (*Colocasia esculenta*), cassava (*Manihot utilissima*), peanuts (*Arachis hypogaea*), tomatoes,

and garden beans. Several species of *Cracca* were grown to study the growth and adaptations to local conditions, and are being used for the extraction of rotenone, tephrosin, and other compounds for insecticidal use.

MACADAMIA NUT

PROPAGATION AND CULTURE

In cooperation with interested growers, several selections of Macadamia trees which have good horticultural records were made. These trees are vigorous and prolific, and the nuts are first class as to size, roasting qualities, and flavor. They are to be maintained as a source of graft wood for the development of true varieties by vegetative propagation.

FIGURE 5.—A recently transplanted grafted Macadamia-nut tree 30 inches high at Kona substation.

The grafting work previously started in an attempt to standardize varieties of the Macadamia nut has proved successful. In brief, the methods worked out are as follows: Macadamia seedlings are grown in the field in rows at right angles 2 feet apart each way. When the seedlings are 18 to 20 months old, they are grafted at about 2 feet from the ground, the union being of the side-tongue graft, details of which are given in a recent circular of the station (*8*, *p.* 8). The method gave about an 80-percent success, and by January 1933, and during each succeeding month, a few trees were dug up and transferred to a permanent place in other fields. The transplanting of the young Macadamia tree is often considered to be difficult. Figure 5 shows one of the trees several weeks after it had been reset in the station orchard.

Seedling trees grafted at 2 feet from the ground may have their crown branches formed anywhere from 3 to 4 feet above ground, which is a very satisfactory height for them in localities subject to considerable wind. Grafted trees tend to be slightly dwarfed, which is a good form for orchard trees, and such trees also tend to come into regular bearing at 6 to 7 years of age. Seedling trees are somewhat erratic and may not bear until 10 or 15 years of age.

At the present time there are approximately 20,000 Macadamia-nut trees distributed mostly among nine plantations in the Territory of Hawaii, and practically all of these are seedlings. The present crop

of Macadamia nuts is a miscellaneous collection varying in many ways and requiring much sorting and selecting until only a comparatively small quantity of high-grade nuts remains for marketing in competition with other kinds of nuts, most of which come from well-organized industries where the growers use only grafted varieties.

HARVESTING AND MARKETING

The ideal sequence from the harvesting of the Macadamia nut to the final cooking and packaging is to husk as soon as the nuts are gathered, then store for 3 or 4 weeks at a temperature not greatly in excess of 75° to 80° F. with good air circulation. Under conditions of ordinary humidity (70 percent saturation), the kernels dry in 3 or 4 weeks to 3–4 percent of moisture, without molding or development of off-flavors. Cracking, cooking, and packing can proceed at once. Excessive temperatures, high humidity, poor air circulation, or too long a period of storage after air-curing are to be avoided.

The main bulk of the crop drops during a 4- or 5-month period, beginning with July. This necessitates storage of the nuts after they are harvested and cured. An experiment was begun to study (1) storage as uncracked nuts versus extracted kernels; (2) temperature of storage—20°, 32°, 40° F., ordinary room temperature, and hot-room temperature; (3) moisture content—air-dry versus dehydrated nuts; (4) time of storage—3 months, 6 months, and 1 year; (5) storage in sealed versus open containers; and (6) storage as roasted nuts versus storage as cured nuts with subsequent roasting. The samples stored for 3 months were opened, roasted, and compared as to texture and flavor. The most important observation made was that the nut absorbs odors from the cold-storage room readily, the extracted kernels more so than the nuts in the shell, but even the latter could not safely be stored with miscellaneous vegetables or other food products. This same tendency to absorb odors has been observed in the use of various fumigants to prevent weevil infestation. The low temperatures had no apparent effect on the nuts after 3 months in cold storage.

As a factory procedure, dehydration of the extracted cured kernels at about 180° F. for several hours until the moisture content is reduced to about 2 percent, with subsequent storage in closed tins at 40° F., is apparently the most satisfactory method. This effectively kills the weevils, prevents molding or rancidity, and permits storage for protracted periods at a nominal cost. Since the Macadamia nut will be sold almost entirely as a roasted product, the storing of the extracted kernels appears to be the most feasible procedure.

One hundred and seventy-eight samples of Macadamia nuts representing all the principal localities in Hawaii where such nuts are being grown, and including both smooth- and rough-shell varieties, were graded as to quality. Monthly samples were taken from each tree throughout the harvesting season when practicable. Otherwise 1 or 2 samples per tree were tested. Through the cooperation of a local Macadamia-nut company, the entire series was run through the regular factory procedure. This consisted in (1) putting the nuts through a centrifugal "gun" which jars the kernel free inside the shell, (2) sizing the nuts into large, medium, small, and culls

(nuts too small to be accepted at the factory), and (3) extracting the kernel by means of a large-scale power cracking machine. Differences among the various samples in any of the three steps can thus be translated into terms of commercial significance.

Results of the year's tests tend to bear out previous observations that, as compared with the rough-shell variety, the smooth-shell nuts are of greater uniformity with less tendency to drop as immature nuts. It cannot be said with certainty that this is due entirely to variety since the smooth-shell and rough-shell samples come from different localities. The early drop of nuts from any given tree is usually high in immature nuts. The main crop, which falls during a 2- or 3-month period, is of the best quality. The late drops are of much better quality than the early drops.

It is especially encouraging to note the excellent quality of nuts from new seedlings growing among coffee in the Kona district. The interplanting of Macadamia and coffee would seem to have some very obvious advantages. Coffee does well under partial shade, so that interplanting with Macadamia at intervals of, say, 50 feet would not appreciably detract from the coffee yields for a long time, and the Macadamia could be brought to bearing age at a nominal cost.

Fertilizer experiments both in the field at Keauhou, Kona, and in pots at the Pensacola Street station, Honolulu, have been continued. It is too early to observe any effects of the different treatments.

COFFEE

VARIETAL STUDIES

The coffee trees used in the present coffee experiments have been in part in cultivation on the Islands of Oahu and Hawaii. The old grove of about 125 trees, located at the Tantalus substation, Island of Oahu, altitude 1,000 feet, which was planted some years ago for varietal study, has also been a source of propagating material. This grove consists of Hawaiian, Liberian, and a few trees each of *Coffea excelsa* and *C. robusta*. The early planting of the present experiment, made in 1931, consisted of 2-year-old trees of Hawaiian and Robusta varieties which are utilized for study of both cultural methods and habits of growth (fig. 6). In 1934 these trees produced a fair crop. The propagating work has been done mostly at the central station in Honolulu.

The work of accumulating seedlings and grafted stock has been in progress during the early part of 1934 for more extensive cultural trials in a new field of 1.66 acres, recently acquired, adjoining the Kona substation. The planting was begun with the early showers of the wet season, which began early in February. The kinds of coffee selected have been based upon the merits of each, as shown either in Hawaii or some other coffee-growing country. These merits or characteristics are vigor, productiveness, quality of grain. and root resistance to some sort of adverse soil conditions, particularly when employed as rootstocks following vegetative methods of propagation.

The names of the coffee varieties, origin, unusual characteristics, and arrangement of planting in the new field at the Kona substation are as follows:

Hawaiian (*Coffea arabica*), Arabian group; nativity, tropical Africa, but reaching Hawaii from Brazil. This variety proved adaptable to Hawaiian conditions; quality very good; planted in experimental field, one row, 22 selected seedling trees; one-half row, 11 grafted trees, scions united with Robusta rootstocks; one-half row, 11 trees grafted on Liberian rootstocks.

FIGURE 6.—Hawaiian coffee (*Coffea arabica*). Four-year-old tree in fruit, 7 feet high, at the Kona substation, Island of Hawaii.

Guatemalan (*C. arabica*), Arabian group; nativity, tropical Africa, but introduced from Guatemala; adaptable to Hawaii; quality very good, probably due to long period of seed selection in a country very favorable to its growth; one row, 23 selected seedlings; one-half row, 12 seedlings for pruning experiments; one-half row, 11 trees selected scions on San Ramon rootstocks; one-

half row, 10 grafted trees on Robusta rootstocks; one-half row, 13 trees on Liberian rootstocks.

Maragogipe (*C. arabica*), Arabian group; originated in Brazil; introduced into Hawaii from Java. It differs from other Arabian coffees in having larger cherries and beans than other varieties of the Arabian group; it also has a late-ripening season. In the field there is one row of selected seedlings for varietal test; one-half row for pruning test; one-half row for scion wood; one-half row, 11 trees grafted on Robusta stocks; one-half row, 12 trees grafted on San Ramon stocks.

Robusta (*Coffea robusta*), Robustoid group; native of Congo, Africa; received in Hawaii from Java, Mozambique, and Panama. It was the main coffee grown in Java in 1920, where it is also extensively used as a rootstock said to be very resistant to adverse conditions. One row of seedling trees for seed production; one row, 22 trees for scion wood; one-half row, 11 trees on Liberian stocks; one-half row, 11 trees on San Ramon stocks.

Padang (*C. arabica*), Arabian group; Sumatra variety. The beans are next largest to Maragogipe. One row of seedling trees for trial production; one-half row, 11 trees on Robusta stocks; one-half row, 11 trees on Liberian stocks.

San Ramon (*C. arabica*), Arabian group; originated in Central America from where it was received in Hawaii; a dwarf variety, fairly true in this respect from seeds; very prolific and late in maturing. One row of seedling trees for production; one-half row, 11 trees on Maragogipe stocks; one-half row, 10 trees on Liberian stocks; one row of seedlings for pruning experiments.

Excelsa (*C. excelsa*), Liberian group; discovered in western Africa. This variety ripens the main part of the crop in spring—cherries do not fall on ripening. The plant is very resistant to adverse soil conditions. One-half row for production; one-fourth row, 6 trees grafted on Liberian stock; one-fourth row, 6 trees on Robusta rootstocks.

Columnaris (*C. arabica*), Arabian group; supposed to be of Javan origin. The trees become large and vigorous and produce heavy crops. It has been known to produce well at an altitude of 3,000 feet. One row of seedlings for trial production and one-half row for rootstocks on which to graft several other varieties have been planted.

Miscellaneous varieties. One row of different kinds of graft unions; also grafts made at different seasons of the year.

PROPAGATION STUDIES

The coffee-grafting work of the past year has included propagation of nursery stock. The seedlings have been germinated in a medium of equal parts of rich loam containing considerable humus and coral sand in ordinary germinating flats of about 3 inches in depth. The seedlings in these flats require from 3 to 4 months' growth to attain sufficient size for transplanting into individual 4-inch containers, which are sufficient for another period of 4 to 6 months' growth. They are then transplanted to 8-inch containers, where they remain without serious root confinement for another 6 months. Within 18 months of growth from germination, the seedling is usually about 1.5 feet high and has a stem diameter near the base of about five-eighths of an inch. The seedlings are grown in the slat house with such other tropical plants as require partial shade. The conditions of coolness and humidity, which are desirable for vigor and uniformity of growth, particularly during the time the stock and scion of the graft are uniting, are thus maintained.

A simple form of graftage which has been employed to some extent in some other countries has been used very successfully at the Hawaii Station with seedlings of either the Liberian or Robustoid group. These kinds of coffee are known to have vigorous roots which are generally resistant to unusually cool or wet soils, attacks of nematodes, and possibly to some other soil disorders. The young seedlings of a month or 6 weeks' growth are transplanted from the

propagating flat to individual 3.5-inch plant pots. After having become established in these containers, which requires about 2 months, the seedlings may be cleft-grafted without the removal of the foliage. In making the union, the stem is cut off a little above the first or second pair of leaves and then split down through the middle for about an inch. The young, comparatively tender scion of about the same diameter and of the desired variety is prepared by cutting the basal end into a narrow wedge as long as the cleft and into which it is inserted and the union bound tightly with a flat strip of moistened raffia. This method of grafting has been successfully employed this year with coffee seedlings up to 18 months old in 8-inch plant pots.

Where very small seedling plants are grafted the small size of stem naturally requires small scions which are only obtainable as seedling scions, but where such scions are from desirable seedling varieties it proves satisfactory. Rootstock seedlings, having a diameter of 0.5 inch or more, however, will unite with larger scions of trees of known quality, thereby producing true varieties.

PRUNING EXPERIMENTS

The two cooperative experiments, begun in 1932, comparing different pruning systems, were continued. These systems are: (1) Secondary vertical, in which much of the plant is permanent and the bearing surface is high up in the top; (2) multiple vertical, in which only 2 to 4 feet of the stump is permanent and new vertical branches are brought out periodically; (3) topping system; (4) modified topping system, in which the base of the plant is like that of the topped system and the top is similar to that of the multiple vertical; (5) tall vertical system in which the verticals are retained for a longer period than in the multiple vertical; (6) leaning vertical system, in which the verticals are maintained in a horizontal position. Plants pruned by these different systems are now showing marked differences in appearance and the results are becoming increasingly valuable as a means of comparing the different systems under identical conditions of soil and climate.

The systematic pruning experiment, in which a study is being made of the feasibility of removing and forcing out the same amount of wood each year, was continued. From the standpoint of field experimentation, such pruning offers possibilities of reducing the tremendous fluctuation in yield of a single tree from year to year which occurs with the ordinary pruning methods.

Girdling, as a means of insuring the development of a low-setting vertical on the old vertical to be removed the following year, was successful in about 90 percent of the girdles. The shoots, which set on, did not always develop rapidly enough to be of appreciable size at the end of the season. There is also some evidence that girdling affected the size of the cherry and the amount of die-back on the girdled vertical. This method requires further experimentation to determine its value.

The coffee die-back experiment was continued. The purpose of this experiment is to limit the amount of bearing of the young tree during the period when excessive bearing often gives the plant a set-back of several years. Under the climatic conditions of the

1933 season, die-back was not apparent in any of the plants in the young orchard in which the experiment is located.

EXPERIMENTS IN HAMAKUA

Fertilization of the coffee-rejuvenation experimental plats was discontinued, but periodic inspections were made of the new growth and systematic pruning was carried on. The moderate pruning method, whereby the old trunk, thickened laterals, and a small amount of young branches are left on the plant, appears to be the best method of renewing growth on the run-down plants. While this is a tedious procedure, it results in a loss of but one crop and can be used on plants of low vitality, where the more drastic stumping would probably kill a considerable number. The so-called "parrot-stick" method, whereby all growth is removed to within about 12 inches of the old trunk, is likewise too drastic to be safely used on run-down plants. Response to fertilization in the Hamakua section is variable. In some fields good increases result; in others there appears to be ample plant food. Improper regulation of shade is often a limiting factor in production in this district.

EXPERIMENTS IN KONA

Results of the 1933–34 harvest of the Kainaliu fertilizer experiment gave 206 bags (100 pounds each) of coffee cherry per acre for the complete-fertilizer (nitrogen-phosphorus-potassium) plats, 202 bags for nitrogen-potassium plats, 51 bags for nitrogen-phosphorus plats, 61 bags for plats receiving nitrogen only, and 65 bags for the check plats. The complete fertilizer used in this experiment is 2,000 pounds per acre of a mixture containing 8 percent each of nitrogen, phosphoric acid (P_2O_5), and potash (K_2O). These results are very similar to those of the two previous seasons.

The nitrogen-phosphorus and nitrogen plats made a fairly good growth of new wood during the previous season, and it seemed possible that the 1933–34 crop from these treatments might approach those of the high-yielding nitrogen-phosphorus-potassium and nitrogen-potassium plats. It became evident as the season progressed that potassium plays an important part in the development of the fruit. In spite of a normal set of fruit, die-back became increasingly evident in the nitrogen-phosphorus and nitrogen plats. The amount of cherry which died back was collected and weighed separately from the normal cherry. In the nitrogen-phosphorus-potassium plats, die-back was at the rate of 0.2 bag per acre; in the nitrogen-potassium plats, 0.8 bag; in the nitrogen-phosphorus plats, 6 bags; in the nitrogen plats, 12 bags; and in the check plats, 4 bags per acre.

Pot experiments at the Pensacola Street station, Honolulu, using coffee seedlings grown in soil from the Kainaliu experiment, show very strikingly this same difference in the functions of phosphorus and potassium in the nutrition of the coffee plant. The trees are 20 months old and fruited for the first time this season. Previous to blooming, the nitrogen-phosphorus-potassium and nitrogen-phosphorus trees were nearly equal in size and vigor, with the nitrogen-potassium plants far smaller. With the appearance of fruit buds, the nitrogen-phosphorus plants began to drop many of their leaves, and scarcely any blossoms opened. The nitrogen-phosphorus-potas-

sium plants blossomed freely and set fruit normally. The nitrogen-potassium plant is small in size but otherwise normal and sturdy. This suggests the possible advantage of different fertilizer formulas for young trees and for full-grown trees in heavy bearing.

Many growers have noticed the tendency of plants fertilized with nitrogen only to die back. Moreover, the quality of the bean appears to be adversely affected. Although the results from the Kainaliu experiment are conclusive for this one location, it should be emphasized that further experimentation is necessary to establish their application to the district as a whole. With this in view, two similar experiments were established, one in North Kona, Holualoa section (1,400 feet altitude), and the other in the Kealakekua section (2,100 feet altitude). The former is in a 5-year-old field, and the latter in an old field of topped coffee. If results of these experiments substantiate the conclusions of the Kainaliu experiment, it will be possible to effect changes in the fertilizer formulas which will result in a much more efficient use of the fertilizer applied.

Analysis of seven samples of coffee cherry taken from widely different locations in Kona showed a fluctuation in the potash content of from 1.67 to 4.03 percent. The pulp from the nitrogen-phosphorus-potassium plats of the Kainaliu experiment contained 3.08 percent, while that from the check plats contained 1.67 percent. Variations in the nitrogen and phosphorus content were apparent but less pronounced. This suggests the possibility of analysis of the coffee pulp as a criterion of the nutritional needs of the coffee plant.

COMPOSTING OF COFFEE PULP

Analysis of the compost from the experimental compost pit at the Kona substation showed a loss of about 50 percent of the total dry matter before decomposition was complete. One ton of fresh coffee pulp, to which 60 pounds of limestone and 25 pounds of superphosphate had been added, produced about 1,000 pounds of final compost with a composition of 2.9 percent nitrogen, 2.7 percent phosphoric acid (P_2O_5), and 3.1 percent potash (K_2O). Observation of the compost pits built by the Kona farmers indicated that anaerobic decomposition proceeds too slowly to be feasible. Apparently, it will be necessary to turn the compost at least twice to effect decomposition in, say, a 7-month period so that the pit can be emptied and the compost applied on the fields during the ensuing summer. To test the effect on speeding up the rate of decomposition, the station compost pit was filled with fresh pulp mixed with thin layers of soil, plus limestone and superphosphate, the purpose of the soil being to furnish a source of organisms capable of more rapid decomposition than those normally present in the coffee pulp.

Farmers recognize the value of coffee pulp as a fertilizer. Fields receiving regular applications show stronger growth with less dieback than those receiving commercial fertilizer only.

ECONOMIC TROPICAL ARBORETUM AND ORCHARDS

The economic tropical arboretum now contains about 600 species. Some of these species, which have already indicated considerable possibilities in Hawaii as cultivated orchard crops, contain many varieties growing in group plantings. Among these groups are:

Annona, avocado, banana, breadfruit, cashew nut, citrus, coffee, date, fig, litchi, longan, Macadamia nut, mamey apple, mango, mulberry, papaya, passion fruit, and sabucaya.

The citrus orchard, which has been developed in connection with many years of experimental work, consists of 238 trees, including 40 different species and varieties. This orchard is a constant source of information in reference to varieties, cultural practices, and insect and plant-disease control, and has supplied propagating material for use in cooperative experiments throughout the Territory. Much of the experimental work in the citrus orchard is discussed in a recent bulletin of the station (*6*).

The avocado, mango, litchi, and date orchards have received attention by the station and have also been made available to the Bureau of Entomology of the United States Department of Agriculture for its fruit-fly investigations.

ANIMAL PRODUCTION

DAIRY

The dairy herd was reduced from 60 to 51 head (including cows, bulls, heifers, and calves) during the year and now consists of 40 Holstein-Friesians and 11 Guernseys. Three young bulls were purchased to replace older animals that were no longer giving satisfactory breeding service.

The general condition of the herd is good. It is free from tuberculosis, and animals positive to the agglutination test for abortion are kept in separate pastures.

The herd not only provides animals for experimental work but is also a laboratory for students in dairy husbandry.

Alfalfa hay was used to supplement the green roughages fed to dairy cows in two 15-week experiments, one with 8 and the other with 6 cows. This resulted in no significant increase in milk yield, but did materially increase the cost of milk production.

Green Sudan grass was compared with green panicum (Para) grass in two experiments each with 6 cows. One experiment lasted 9 and the other 12 weeks. In each case the cows consumed more of the Sudan grass and the milk yields were slightly higher.

The leaves and stumps of pineapple plants (shredded) were fed to three 600-pound Holstein heifers as their sole roughage for 147 days. Consumption ranged from 22 to 45 pounds daily per heifer, depending on the kind and quantity of supplementary concentrates given. No high value was indicated for pineapple plants in this trial, but it was demonstrated that cattle will eat considerable quantities of them and that plants in old or abandoned pineapple fields may be used as emergency feeds in periods of drought.

Cane molasses to the extent of 25 percent of the concentrate mixture was fed for a 7-year period to many cows in the herd (153 cow-years) and the records of 6 years on a nonmolasses ration (146 cow-years) were used as controls. In general, the results show that, when properly supplemented with high-protein feeds, cane molasses in the amounts indicated does not adversely affect production or reproduction or increase the number of abortions and it does result in a material saving in the cost of milk production under conditions prevailing in Hawaii.

No definite benefits were noted from feeding sprouted oats to cows with an irregular breeding behavior, and results to date indicate that under conditions prevailing in Hawaii (green feed available the year round) this method of correcting breeding troubles has little value. To date, 53 cows have been fed sprouted oats.

SWINE

At the close of the fiscal year 1934 the swine herd included 5 Berkshire and 6 Tamworth breeding animals and 17 smaller pigs. At the beginning of the year the herd numbered 44 animals. The reduction in the size of the herd was brought about as a necessary economy measure.

Further work on the feeding value of avocados or papayas (cull or excess fruits in regions distant from market) indicate a fairly high value for avocados and a much lower value for papayas.

Cooked taro scraps (refuse from poi factories) were found to have a fairly high value as a hog feed.

Feeding sprouted oats to sows with an irregular breeding behavior was continued. Not all the sows were benefited but their records were better than those of an equal number of controls, also with breeding troubles, to which sprouted oats was not fed.

POULTRY

The poultry husbandry division maintains a flock of approximately 2,000 chickens, turkeys, and guinea fowls, comprised of breeds commonly found on the commercial farms in Hawaii, for purposes of instruction, demonstration, and research.

ARTIFICIAL ILLUMINATION FOR LAYING STOCK

Pullets that are hatched in November, December, January, and February have a tendency to go into a partial or complete molt before a full year of laying. All-night illumination was tried on early-hatched pullets but proved to be unsatisfactory. For the past 2 years the lights have been turned on at 4 a. m., beginning on September 1 and terminating on March 1. Analysis of the data gathered over the past 2 years shows that the 4 a. m. lighting system has given satisfactory results. Early-hatched pullets did not go into a complete molt during the fall months; likewise the partial molt was reduced approximately 75 percent by the increased length of day. Body weight, after a year of laying, was very satisfactory; practically in all hens a decided gain was noted. Egg production has been greatly increased. The pens on artificial lighting averaged 50 percent more eggs during the months that they were under lights over that produced by the check pens receiving no artificial illumination. A greater number of culls appeared in the check pens, although the mortality was approximately the same for both groups.

A few poultrymen have cooperated with the station in this work, using their commercial flocks from which to obtain data under field conditions. Data from these field trials have not been analyzed to date; however, an increased production and less culls have been reported by all collaborators.

TREE KALE (CHOU MOELLIER) AS A SOURCE OF GREEN FEED FOR POULTRY

Comparison of tree kale with alfalfa as a source of green feed for poultry, which has been in progress for 2 years, indicates that tree

kale is comparable with alfalfa for egg production, fertility, hatchability, and body development.

BATTERIES FOR LAYING AND BREEDING STOCK

The first attempt to house laying hens in hen batteries was made during the year by the Hawaii Station. The hens were divided into three groups according to their breeding, development, and condition. One-half the birds in each group received a fermented yeast mash daily containing 1 percent of "animal-poultry yeast"; furthermore, the three groups were on an entirely different feeding method. Three types of commercial feeding methods were used, namely, the all-mash, mash and scratch, and pellets and scratch. Fermented yeast mash gave best results in all three feeding methods above mentioned. The birds were in better condition at the end of the experiment; they laid approximately 30 eggs more per hen when fed 1 percent of yeast in mash that was fermented for 18 hours. Mortality was approximately the same in all groups. The average yearly production per hen for the entire group was 200.6 eggs. One hen laid 300 eggs and another 297 during the period of the experiment which lasted 365 days.

PLANTATION BACK-YARD POULTRY HOUSES

Four types of houses, each with a floor area of 72 square feet and accommodating 25 hens, were tried with the object of finding a house that was cheap and yet efficient for the back-yard plantation poultry raiser. One year of work on this problem shows that egg production was maintained in a satisfactory manner in all four houses; that the birds in an all-lath house gave the lowest production, whereas the best production was obtained from birds in an 8 by 9 foot house with a solid back and a wire front.

Considerable cannibalism in the form of feather pulling was noted in all four houses. Previous trials at the Hawaii Station have shown that where birds were kept in close confinement, cannibalism was one of the most serious problems with which to contend. Blueprints of the four types of houses have been made and are available to those interested.

SOREHEAD (FOWL POX) CONTROL

In studies of sorehead extending over 7 years, the object has been to determine the method of transmission of the disease to chicks, poults, and squabs, and also to determine the effects of a "live virus" vaccine in developing immunity against the disease. The results of elimination of mosquitoes from the house and run indicate that the mosquito carries the virus to the chick. Chicks 4 to 12 weeks old and poults 3 to 16 weeks old have been successfully vaccinated with a live virus vaccine prepared by the station. In field trials, as a demonstration to show the value of fowl-pox vaccine, approximately 250,000 chicks have been vaccinated successfully. The procedure and the results of this experiment under laboratory and field conditions are described in detail in a circular of the station (*3*).

GIZZARD-WORM CONTROL

The object of this investigation is to determine the cause of the gizzard-worm infestation in Hawaii, particularly in regard to an intermediate host which may be responsible for this new disease. It

was started only within the last quarter of the fiscal year 1934. Considerable losses have been caused directly or indirectly by this worm. One farm reports a loss of approximately 3,000 hens in a period of 1 year. The worm is found on all of the islands; hardly a farm has escaped an attack of this parasite. Not only a high mortality but apparently a decided lowering of egg production has resulted.

There has been very little scientific research on this worm by mainland institutions, primarily because the worm has not infested the large poultry centers. All information received from mainland investigators state that the grasshopper is the intermediate host responsible for the gizzard worm. The station has made a study of infected gizzards, noting especially the physiological characteristic of both male and female worms. Several of the common insects found on most poultry farms in Hawaii have been studied, with no indication as to the intermediate host. Gizzard-worm eggs are being fed to baby chicks to determine whether or not infestation may occur without an intermediate host. Nothing conclusive as to an intermediate host or any other means by which the infestation has appeared in Hawaii has yet been found.

FOOD AND NUTRITION

IODINE CONTENT OF SOME HAWAIIAN MARINE FOOD PRODUCTS

In a continuation of an investigation to determine the iodine content of Hawaiian foods, 18 of the principal fish and 12 of the most widely used seaweeds have been analyzed. The general procedure followed was Remington's modification of McClendon's method, but it was found necessary to alter Remington's procedure in consideration of the particular characteristics of marine foods. To avoid loss of iodine, the bulk of the final ash was increased by adding to each sample before ashing 1 g of calcium carbonate and 2 cc of a saturated solution of sodium carbonate and moistening with hot water. This modified method replaced the Remington procedure, which involved soaking the sample with a 2-percent aqueous solution of sodium carbonate.

The experiments were carried out in duplicate and the results tabulated below show amounts of iodine expressed in parts per billion of the dry sample:

TABLE 1.—*Iodine content (in parts per billion of dry sample) of different marine foods*

Kind of food	Sample 1	Sample 2	Kind of food	Sample 1	Sample 2
Fish:			Fish—Continued		
Ahi	2,100	2,100	Ulua	2,000	1,800
Aholiholi	3,300	3,570	Weke ula	1,910	1,940
Aku	2,600	2,700	Seaweed:		
Amaama	1,500	1,800	Akiaki	411,000	412,000
Au	2,270	2,300	Alaula	127,000	134,000
Awa	2,600	2,750	Eleele	6,408	6,403
Hapuu	2,390	2,320	Huluhuluwaena	157,000	143,000
Kahala	2,500	2,540	Huna	1,980	1,970
Kala	3,590	3,500	Kala	487,000	464,000
Kawakawa	2,700	2,790	Kohu	5,100	5,500
Mahimahi	1,941	1,944	Lipeepee	13,600	13,700
Moelua	2,600	2,640	Lipoa	85,400	85,800
Moi	1,950	2,000	Manauea	143,700	146,300
Oio	1,950	1,900	Opihi	89,100	89,900
Opelu	2,080	2,020	Palahalaha	5,200	5,000
Uhu	5,300	5,000			

STEROL CONTENT AND VITAMIN VALUE OF AVOCADO OIL

The study of avocado oil for its vitamin D value was continued in a new series of feeding experiments with white rats. Animals were fed irradiated and nonirradiated samples of avocado sterol in alcoholic solution. The repetition of the entire vitamin D investigation was undertaken. In previous feeding experiments certain difficulties encountered led to inconsistencies in results. It is anticipated that the present set of animal experiments will lead to more definite conclusions concerning the vitamin D value of avocado oil and avocado sterol.

A CHEMICAL STUDY OF SOME HAWAIIAN PLANTS

POISONOUS PLANTS

Recognizing the fact that there are many poisonous plants of obnoxious character in the Hawaiian Islands, an investigation was started during the year to determine the chemical and physiological nature of the poisons in certain of the plants, and to isolate useful drugs and medicinals. Three plants, pamakani (*Eupatorium glandulosum*), akia, and air plant, were investigated for two common classes of plant poison, alkaloids and cyanogenetic glucosides. The three plants have been shown to be free from detectable quantities of alkaloids.

From pamakani a white crystalline solid melting at 68.5° C. was isolated which analysis showed to have the empirical formula $C_{25}H_{56}O$. Work is in progress to establish the chemical nature and the physiological action of this substance. Similar studies are in progress with akia and air plant and will be extended to other poisonous Hawaiian plants, about 80 of which have been listed.

PASSION FRUIT

The juice of the passion fruit is known to keep unusually long. A chemical and bacteriological study of the various components of the juice was made to determine the cause and, if possible, to isolate a preservative. No alkaloids or common preservatives were found and the conclusion was reached that the unusual keeping qualities of passion-fruit juice are due to high acidity.

VITAMIN B CONTENT OF FRESH DAIKON

Previous studies, which showed the nutritive value of vegetables to be increased by the Japanese method of pickling with salt and rice bran, were continued with the daikon or Japanese white radish (*Raphanus sativus longipinnatus*). The vitamin B of the rice bran was found to be absorbed by the daikon.

VITAMINS A AND D IN THE OPIHI (HAWAIIAN LIMPET)

Biological tests to compare the vitamin A and D content of the opihi with the international standards for these two vitamins showed this shellfish to be an excellent source of vitamin A and a very good source of vitamin D.

ANEMIA STUDIES

Anemia studies in cooperation with C. J. Hamre of the zoology department of the University of Hawaii were continued. The

enlarged spleens found at autopsy in anemic rats were correlated with definite stages of recovery from anemia, judging from the blood studies and histology of the spleens. Studies of young rats from birth to maturity showed similar correlations with the blood picture and the conditions of the spleens.

PROTEIN OF THE PIGEONPEA

Feeding experiments with white rats indicated that cystine had a growth-supplementing value when pigeonpea-seed meal was fed at a level to provide 11 percent of the protein in the diet, whereas, when fed at a level of 8 percent, cystine showed no supplementary value, possibly because at this level some other amino acid is the limiting factor.

VITAMIN CONTENT OF SOME HAWAIIAN FRUITS

Biological tests showed the papaya to be an excellent source of vitamins A and C and a good source of vitamin G, but only a fair source of B. Analyses showed the papaya to be a good source of calcium and sugar. The papaya is therefore a fruit of high nutritive value and should be more widely grown and used by all the peoples of Hawaii.

Although figs are a better source of calcium and iron than are papayas, figs are a fair or poor source of all the vitamins tested.

Pohas, though not an important or widely used fruit, were tested and found to be a good source of vitamins A, B, and C.

Previous experiments have shown that guava juice, prepared as for jelly making, has a high vitamin C content. The juice was prepared by slicing ripe guavas, placing in a saucepan and almost covering with water, bringing to a boil, and boiling gently for 10 to 15 minutes. The juice was stirred frequently to prevent scorching and then drained through a clean flour sack or other cloth. It was then ready for use. Experiments with 14 guinea pigs, 7 of which were fed daily 3 cc of guava juice and 7 a quantity of jelly equivalent to 2 cc of guava juice, showed little or no loss of vitamin C when the juice was made into jelly. This same jelly had no demonstrable quantity of vitamin A.

With the cooperation of a local pediatritian and the nurses at two of the well-baby clinics in Honolulu, it was possible to try out the use of guava juice in place of orange juice as an antiscorbutic for 10 normal babies. Several hundred quarts of guava juice were prepared and bottled, using an ordinary bottle capper. When stored in a dark place at room temperature, the juice kept perfectly for months. The guava juice, given out at the clinic and delivered to the homes, was the only antiscorbutic given for 6 months. The results showed that guava juice, prepared as for jelly making, may serve as a satisfactory antiscorbutic for infants. Many of the babies showed a greater rate of gain than the average for the clinic babies and there was no evidence that the guava juice disagreed with infants of 2 months and older.

JAPANESE FOODS AS SOURCES OF THE VITAMINS

Reports from Japan indicate that tofu (soybean curd) and miso (fermented soybeans and rice) are poor sources of vitamin B, but

preliminary tests in the station laboratory have shown them to be good sources of this vitamin. In addition to their value as sources of calcium, phosphorus, and iron, these two foods should be stressed for the Japanese diet because of their vitamin B content.

Preliminary tests showed miso to have no demonstrable quantity of vitamin A but to have considerable vitamin G.

Lotus root, used by both Japanese and Chinese, was found to have little or no vitamin A and to be only a fair source of vitamins B and G.

Chirimen-iriko, a very small dried fish used by the Japanese (*5, p. 15*), showed little or no vitamin G; rats fed 3 grams daily gained no better than the control. The dried fish, however, proved to be a good source of vitamin A, and a very good source of vitamin D.

HALEAKALA SUBSTATION

Work was continued at the Haleakala substation (elevation 2,162 feet) and on the four associated tracts located at elevation intervals of about 1,000 feet, with the highest at about 6,000 feet.

The extreme conditions of drought in the summer and fall of 1933 enabled the superior grasses and legume varieties under test to stand out in sharp contrast to the native range grasses in the associated pasture areas. The forage crops under test consisted of 32 varieties of grasses, 166 lots of pigeonpeas, 17 varieties of clover, as well as plantings of alfalfa, vetches, and *Meibomia rensoni.*

The root and tuber crops included edible canna, cassava, taro, arrowroot, as well as 25 varieties of potatoes, including the Bliss Triumph, upon which special work is being done to determine its value for new potato shipments to the mainland during January and February, when the markets are otherwise practically bare of new potatoes.

The cereal crops under test included corn, popcorn, barley, oats, rye, and sorghum. There were also planted some 27 varieties of green-manure crops and 28 lots of soybeans.

Twenty-one different varieties of vegetables were planted. The small fruits under test included strawberries, dewberries, Logan blackberries, akala berries, pohas, and 17 varieties of grapes, of which the Isabella appears to be the only one adapted to the local conditions. Fruit trees included avocado, mango, mulberry, prune, nectarine, orange, lime, Bartlett pear, pecan, Persian (English) walnut, almond, Japanese persimmon, apple, cherimoya, loquat, fig, longan, pomegranate, Macadamia nut, guava, mamey apple, star-apple, mountain apple, and mabolo.

Planting material of the more promising forage crops, vegetables, and small fruits was distributed to cooperators who wished to make tests under their local conditions.

The year as a whole was characterized by a very low rainfall. During the 6-month period from May 1 to October 31, 1933, the following precipitation (all in the form of light showers) was recorded: Haleakala substation, 4.93 inches; Olinda, 1.71; Ukelele, 2.07; Mountain Paddock, 0.96; Puu Nianiau, 4.33.

KONA SUBSTATION

The Kona substation, Island of Hawaii, continued to devote its principal energies to the investigation of the various problems affecting the coffee industry. An additional tract of 1.66 acres of adjoining land was obtained during the year and devoted to the testing of different species and varieties of coffee obtained from various parts of the Tropics.

The coffee projects under way had to do with species and variety testing, culture, pruning, and fertilizer-requirement studies, as well as the determination of the best methods, seasons, and stocks for budding and grafting operations. Evidence points to the desirability of utilizing only budded and grafted stock to insure uniformity of yield and a standardized product in connection with coffee and Macadamia nuts, as well as avocado, mangoes, and citrus.

Variety and cultural tests were continued in connection with numerous species and varieties of miscellaneous fruits thought to be of possible promise. These plantings include breadfruit, cashew nuts, cherimoya, figs, Japanese persimmons, litchi fruits, olives, passion fruit, sweetpotato, tomato, and various cover crops which, with the sweetpotatoes and tomatoes, have been intercropped between the rows of young fruit trees.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the joint supervision of the Office of Experiment Stations, U. S. Department of Agriculture, and the University of Hawaii]

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